About the relevance of the concept of risk acceptability in the risk management process : a decisional approach in the French national context

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About the relevance of the concept of « risk acceptability » in the risk analysis and risk management process: A decisional approach in the French national context

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1. Abstract

*A rapid view to the evolution of the legal context at the national European and international level shows a need to introduce both more "visibility" and more "legibility" on the **way** the decisions in risk analysis and risk management are taken. This can be introduced by: ft) giving an image of **what** the scientific and the experts agree to be the technical "state of the Art" in there respective discipline to reduce and control hazardous activities; (ii) improving the way the population and the other stakeholders are involved and participate to the risk management process.*

***In** France, the Toulouse disaster has revealed a real need to improve the way decisions are taken in the risk prevention processes. In this paper, we will show how the **establish** concept of "risks acceptability" can induce bias on the way risk analysis are performed in the context of the hazard induced by industrial activities. We will show that there is a need to distinguish the acceptability known as "technical" from the one known as "social". We will then propose a new enlightenment on the way risk analysis are performed in Safety Studies and then discuss about the issue of land-use planning in France using "Risk prevention plans" (TRPP) around SEVESO sites.*

*Keywords: Governance, decision **aid**, risk analysis, risk acceptability, land-use.*

2. Prevention of technological risks: The French context

The various industrial catastrophes, such as Bhopal (for the chemical industry, December 1984), Chernobyl (for nuclear industry, April 1986), Enschede (related to the storage fire-works, May 2000), and more recently the Toulouse AZF factory (related to the storage off specification ammonium-nitrate, September 21, 2001), revealed the need to go towards a greater control of the risks and their consequences and towards a stronger implication of the various stakeholders in the industrial risks prevention process.

In France, the Toulouse accident (2001) marks a turning in the industrial risk prevention process. Indeed, with more than 30 deaths in a radius of 500 meters, thousands of wounded and more than 26000 residences damaged on a radius of 3 kilometers [22], this accident has revealed the following needs:

1. *Control of the risks by acting on their source.* This mainly consists in improving the way the risks control demonstration is carried out within the framework of the Safety Studies (SS).

2. *Reduction of the vulnerability around the Seveso sites (High Threshold).* This consists in using the experience of the Risk Prevention Plans, carried out in the context of natural hazard, and proposes Technological Risk Prevention Plans (TRPP).

3. *More implication and more dialogue with the various actors in the risk prevention process.* This consists in:

    - instituting a greater participation of the employee in the risks control process, with a widening of the Health, Safety and Working Conditions Comity (HSWCC) missions;

    - going towards more implication of the various actors of risk prevention using the Local Committees of Information and Dialogue (LCID).

These three objectives aim at increasing the transparency of the risk analysis process, and at going towards a greater coordination between the different actors in of the preventive risk management.

In what follows, we will highlight the link between risk acceptability and the decision-making processes in risk prevention.

The first part of this paper highlights the relation between acceptability concept and the risk prevention process, in general and within the French context. The second part of this paper presents the estimation of a risk acceptability level within the framework of the SS. This part is based on a critical analysis of about thirty "criticality grid". The third and last part of this paper examines the acceptability concept within the framework of TRPP by studying the role of the dialogue process in urbanization control around the Seveso sites.

3. Risk acceptability and technological risks prevention

Risk is more than a simple mathematical formulation. Risk is a relative notion that depends on its perception [5][26][1].

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[1] With, Simon and March (1959, 1991) rationality is initially limited culturally (Simon, 1957, 1966, 1982; Simon and March, 1991), to be widened, in the second time, by Bourdieu (1992) with limited rationality socially and a genetically (Delavallée, 1995).

2.1. Short history of a relative concept: risk and perception

Risk definition was strongly influenced by the economics concerns in decision problems. Indeed, Frank Knight [17] defines a standard situation of decision where a rational actor conscious of his preferences must, by knowing the future consequences of a set of proposed decisions, choose among these the best one. In this context, if the actor does not have any possibility of checking the veracity of the evaluation of the suggested alternative consequences, then the decision situation is known as "uncertain". On the other hand, if uncertainty is measurable then this is known as a risk and the decision in this case is based on a probability calculation [19]. Here, the risk is defined in opposition to uncertainty.

In the Sixties, the study of risks induced by the large technical systems, such as the industrial facilities, made it possible to add to the risk a new component. The risk was then defined as a quantifiable mono-dimensional value resulting from the combination of the probability and the intensity of an "event" [16]. The advent of the social choice theory gives to the risk its social dimension [3][7][8][18]. Luhmann [18] provided an interesting description of the distinction between "undergone decision" and " taken decision "; between danger and risk. For Luhmann, risk, defines a context where the future potential damage is the consequences of a "taken decision". The danger relates to the contexts where the decision is " undergone".

Nowadays, the interest for the study of "risk" invested various disciplinary fields. One speaks then about "natural risk"; "technological risk"; "chemical risk"; "management risk"; "risk of information systems"; "major risk"; "military risk" [2]. Due to this diversity, many definitions of the risk concepts are available (more then sixty-eight) [2]. In these various risk contexts the risk evaluation aims at organizing the available knowledge "to highlight" the "world" uncertainties [15] to enable the decision-makers to take the best decisions. This cannot be done only on the basis of one single rationality i.e. the technical rationality. Values, attitudes, preferences as well as motivations in choice-making situations vary from one actor to another [12][23][24].

In what follows, the risk is defined as a combination of "hazard" and "vulnerable stakes" [28].

2.2. Risk acceptability

Acceptability is commonly defined as a "Set of conditions that make something acceptable" [1]. In an other hand, what is considered as tolerable is defined as "what one can admit by indulgence" [1]. Using these two definitions, one can say that risk is sometimes accepted and sometimes tolerated.

2.2.1. ALARA/ ALARP :« As Low As Reasonably Achievable » and « As Low As Reasonably Practicable ».

The Health and Safety Executive [9][10][11] in England and the VROM in Netherlands [29] were the first to introduce the two concepts of "acceptable risk and/or tolerable risk" in the risks prevention process.

For the HSE, the acceptable risk represents "what is negligible" and the tolerable one "what is not negligible considering the possibility of a benefit and the emergence of a confidence in risk control measures". Within this framework, the standards defining a risk threshold, beyond which no reduction action were required, used the tolerable risk approach. That means that risk reduction measures must be established according to what is reasonable **"and/or"** practicable.

For the Netherlands, the Environment Ministry has defined a contextual set of "acceptable" and of "negligible" threshold. The risks above the acceptable threshold are prohibited and it is advisable to reduce them until the limit of the negligible risk. The risk level considered as "negligible" is fixed at 100 times lower than the acceptable threshold.

HSE and **VROM** approaches are both based on the **ALARA/ ALARP** approaches « As Low As Reasonably Achievable » and « As Low As Reasonably Practicable » used for nuclear risks. The **ALARA/ALARP** approaches consider a continuity between exposition and effects and do not help to identify an acceptable risk threshold. Thus, the values of the acceptable individual excess risk[2] threshold is different for the HSE (10^{-4} per annum for the public living in the vicinity of the factory site) and VROM (10^{-6} per annum for the public living in the vicinity of the factory site).

In France, acceptable risk is "what is legally allowed, knowing the expected benefit" **[6]**. Different acceptable risk thresholds are defined in **different** regulatory risk assessment processes: the Safety **Studies**[3] and the **TRPP**. The first one aims at identifying whether the risk reduction at the source is enough. The second one examines if additional measures should be taken to reduce the vulnerability. Two acceptable risk levels are thus defined. The first one is based on the ALARA principle: the lowers risk level achievable with the techniques available to the plant operator. The second one should take into account the expectations of the exposed populations.

2.2.2. Acceptability within the framework of **the Safetv** Study (SS)

The Safety Study (SS) is the industrialist demonstration of the control of risks induced by its activity. In the French present **context**, the SS is used as a reference for further land-use planning decisions, for emergency planning and for public information **[4]**. The SS is based on risk analysis procedure that consists in:

1. Identifying a set of scenarios of accident. This consists mainly in:
    - describing the site and the installations environment ;
    - identifying danger potentials of the installations ;
    - developing experience feedback of the last accidents ;
2. Valuing quotation of the **criticality** of the set of scenarios according to their probability of occurrence and of the gravity of their consequences.
3. Taking risk reduction measures (of technical and organizational nature) for the set of scenarios judged as unacceptable.

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[2] Defined as the probability for one person to die from the consequences of the hazard.

[3] Etude de Danger.

The choice of measures and their impacts on risk reduction is done using a support interface called " **criticality** grids " (Table 1).

Table 1. An example of a criticality grid

Gravity 4	4.1	4.2	4.3	4.4
Gravity 3	3.1	3.2	3.3	3.4
Gravity 2	2.1	2.2	2.3	2.4
Gravity 1	1.1	1.2	1.3	1.4
	Frequency 1	Frequency 2	Frequency 3	Frequency 4

(dark shading)	Risks considered to be unacceptable	Measures must be **proposed.**
(light shading)	Critical risks	Safety measures considered being sufficient according with the **level** of risk.

This grid helps to estimate a level of criticality using the following information: the level of probability of occurrence and the gravity level of the consequences of a scenario. The level of criticality helps to identify the unacceptable risk. Thus, this grid is a decision-aid tool that helps to:

(i) identify a risk hierarchy on major accident scenarios ;

(ii) define measures to reduce the risk at its source ;

(iii) draft the **TRPP** and the Specific Intervention Plans for risk management around the industrial site.

As we can notice, the acceptability estimated, using the criticality grid, for the SS help to "identify what can be perceived as tolerable, for the stakeholders, once damages and losses occurred caused by the occurrence of an accidental scenario". In the context of the SS, the stakeholders are those who are implied in risk analysis process: a person in charge of the considered **installation**, a person in charge of the security, an operator, a person in charge of the maintenance, an engineering specialist of **the** considered installation [14]. Thus, the acceptability in the Safety Study is a "technical" one. A set of explicit or implicit criteria (e.g. Ethiques, moral, economic, political etc.) and of practical constraints for the industrial site are identified to estimate the technical acceptability and than to choose the appropriate measures to reduce risk

2.2.3. Acceptability within the framework of Technological Risks Prevention Plans (TRPP)

The French law n° 2003-699 of July 30, 2003, relating to "the prevention of the technological and natural risks and to the damages compensation", has introduce a distinction between the reduction of the risk to the source (hazard) and the urbanization control around Seveso sites. This distinction became effective in two different procedures: the Safety Study (SS) and the Technological Risks Prevention Plan (TRPP).

The Technological Risks Plans of Prevention (TRPP) aims at limiting the direct or indirect effects on public health and safety directly or by pollution of the medium of an accidental event accidents likely to occur in the installations at the major risks being able to involve effects. This will consist in delimiting risks exposure perimeters according to the nature, the intensity of the technological risks described in the SS and the proposed prevention measures.

At the interior of the perimeters of exposure to the risks three types of zones are given according to the nature of the risks, their gravity, their probability and their kinetics. These zones, respectively called zones of urban right of pre-emption, zones of renunciation and zones of expropriation, represent three constraints of urbanization with which are associated the financial mechanisms with adequate compensation (Figure 1).

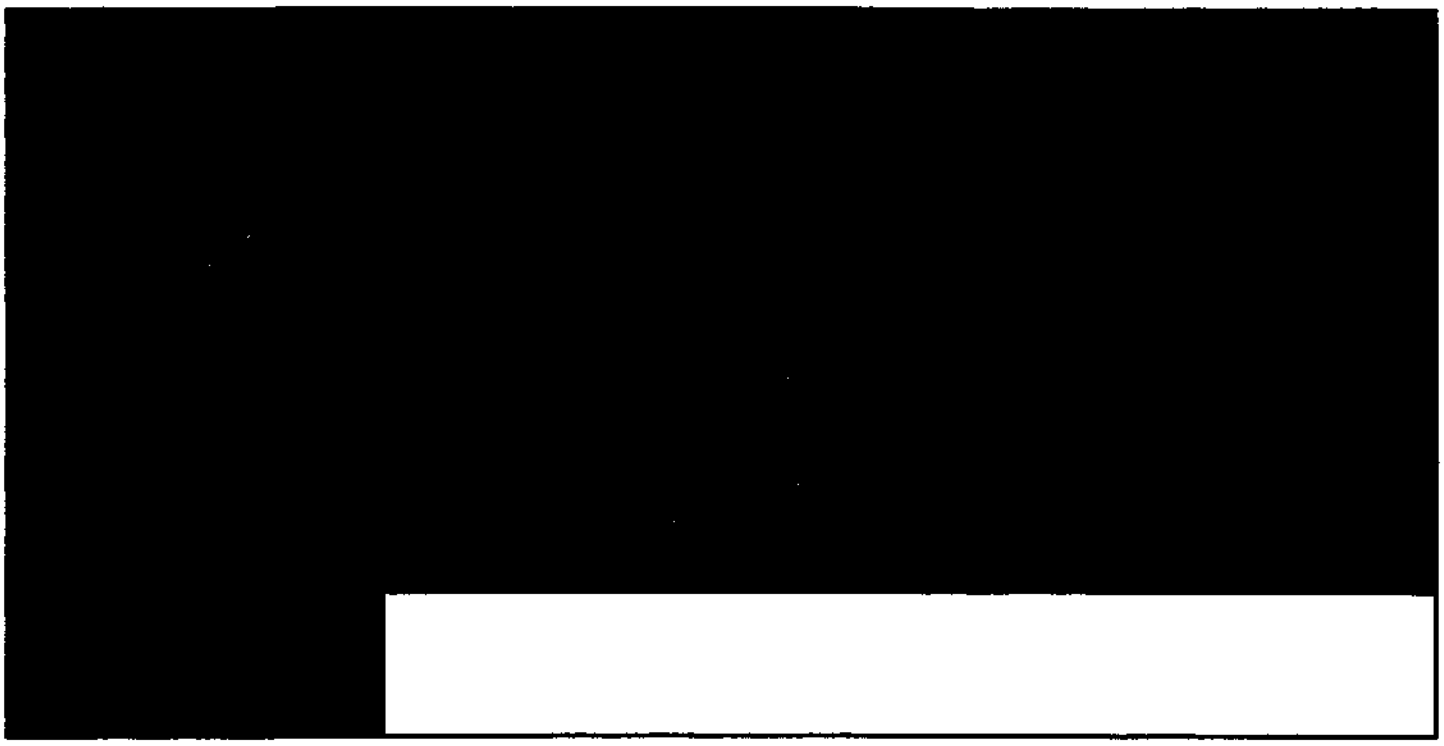


Figure 1. Various zones defined within the framework of the Technological Risks Preventions

The approval of zoning (expropriation, pre-emption and renunciation) and the corresponding measures is done by a committee of actors representing the various typologies of stakeholders involved in the risk prevention process (administration, authorities local, owners, residents and employees). This committee "Local Committee of Information and Dialogue" (LCID) is set up by the Prefect in each risk area where hazardous installations are identified. The LCID aims at providing to the decision -maker an estimation of the local risk perception of the acceptability both of the accidental risk itself, of the land use planning restrictions or technical measures that could be taken to reduce the risk [21]. Thus, this societal acceptability is obtained by providing more proximity between the actors involved in the TRPP within the frame of a dialogue and information process.

From this first general presentation of the acceptability, it can be concluded that semantic and methodological differentiation of acceptability concept is needed for both Safety Studies (SS) (technical acceptability) and Technological Risks Prevention Plans (TRPP) (societal acceptability).

4. Technical acceptability within the framework of Safety Studies: A critical study of 29 "criticality grids"

An analysis of 29 " criticality grids " usually used in risk analysis in various fields (e.g. natural, industrial, social, etc.) and countries, was realized. This analysis aim at (i) identifying the conditions and the approach used to estimate risk acceptability in the Safety Studies (SS), and (ii) highlighting heterogeneity of practice used to estimate the technical acceptability of risk [20]. This study contain two levels of analysis: a macro-analysis that has revealed some deficits on the "criticality grid" and a **micro-analysis** which provide a set of criteria explaining the noticed convergence or divergence between the various studied grids.

On this paper, we will present the conclusions of the **macro-analysis** and then propose some improvements for "criticality grid" and to the way the technical acceptability on estimated in the Safety Studies.

3.1. A macro-analysis of the set of 29 "criticality grid"

The analysis of the 29 grids has revealed:

- needs in experience feedback structuring ;
- biases in risk scale transition from qualitative to quantitative ;
- difficulties in evaluating accidents occurrence probability ;
- difficulties in identifying the level (or a set of criteria) where accidental scenarios are considered as non tolerable or non acceptable ;

In addition to these observations, some deficits were identified:

a). *Structural **deficit.*** These deficits represent gravity and probability scales biases in the way the levels of risk and the level of acceptability are identified.

- For the "gravity" scale. The gravity of an accidental scenario is sometimes defined with reference to the consequences on people, on goods, on **environment**, and on reputation of the company. Each consequence takes a value on a distinct scale sometimes qualitative and sometimes quantitative. The following non appropriate practices are noticed:
  - o If the different consequence scale evaluation are similarly incremented, then for a selected level of gravity a direct correspondence (correlation) between different consequences is considered (ex. consequence on people, consequence on environment).
  - o Subjectivity in identifying a level of gravity: non-explicit criteria are proposed.
- For the probability scale, we can notice:
  - o Occurrence references are heterogeneous for a same scale: temporal reference, **decisional** reference, and spatial reference.
  - o The use of different probability **approaches**: *frequentist, **possibilitic**,* etc.
- For the risk criticality level. The criticality is obtained by crossing two dimensions: probability and gravity. This aggregation presents a significant loss of information. Moreover, the criticality level can differ and can take different significances according to the method or the approach used to estimate the level of probability and the level of gravity. The last remark concern the fact that a quantitative significance is given to the criticality level even if the information used to obtain this level is purely qualitative.

b). *Deficit of standardization.* The analysis of the criticality grids shows a great diversity of practice. Thus, if the criticality grid must represent a decision-aid tool, it becomes necessary to converge towards a set of criteria, a set of methods and coherent structure of grid making it possible to be used as a basis for a common vocabulary between the various actors of the decision. This is necessary to go toward more objectivity, and more homogeneity in risk evaluation of a level of criticality of the set of scenarios selected for the risk analysis.

c). *Deficit in their communicationjunction.* The criticality grid is a decision-aid tool that must respect the fact that the criticality level and the acceptability level must have the same meaning for all the actors involved in the risk analysis process. Thus, if this is not true, that means that the Safety Study is not robust.

In what follows, we will give some suggestions to improve the way acceptability is evaluated in the safety studies.

3.2. Suggestion of improvement of the current grids

A "criticality grid" is both a decision-aid tool and a dialogue tool. The analysis of various grids was done in the framework of a program aiming at improving the current practices in risk assessment for a better risk prevention. The suggestions below were formulated on the basis of the conclusion of this program.

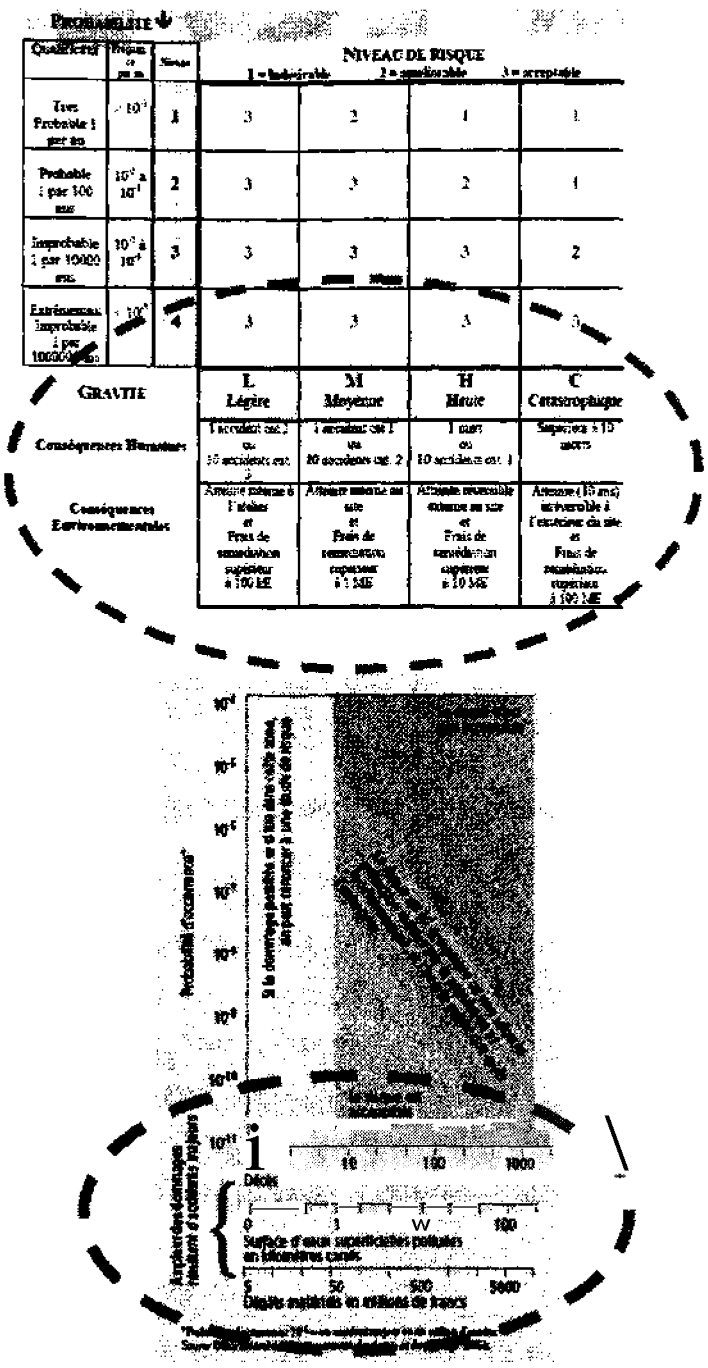
3.2.1. The nature of the scale

The "nature of the scale" must be considered for both gravity and probability estimation in order to avoid wrong interpretations of numbers. By definition, a scale helps to provide an evaluation to a given scenario according to its effects and its characteristics.

A scale is known as « ordinal » if the distance between two rungs does not have meaning (a, Figure 2). This scale can be verbal or numerical (qualitative scale) [25].

A scale is said to be quantitative when this one is a numerical one and when the rungs are defined according to a specific unit [25]. In this scale a sense is given to « having no quantity » (rung 0) and the ration between two given rungs is equal to the ratio of the given rung number (b, Figure 2).

A scale is considered as hybrid when this one balances between the two precedent scales. The interval scales are considered as hybrid scales because the ratio between two different numbers associated to an interval has a meaning when the ratio between to number associated to a rung has no meaning (Example: Temperature level using Celsius or Fahrenheit scale).



(a) (b)

Figure 2. Example of a qualitative gravity scale (RODIA criticality grid) (a) and an example of quantitative gravity scale (OFEFP criticality grid) (b)

The following suggestions can be done considering given precision on scale nature:

a). The level ofprobability. The définition of the probability scale depends strongly on the nature and the quantity of the available data. Thus, even if various evaluation procedures can be imagined to identify a level of probability, it is necessary to show the correlation between them (Table *2)*.

Table 2. 4 levels of probability: two approaches according to the availability of data

Level of probability		
Column 1	Column 2	Column 3
Qualitative approach (if not a lot of data)	Quantified or **semi-quantified** approach (data)	Probability scale used in the criticality grid
Improbable**	**10^{-n1}***	1
Occasional**	**10^{-n2}***	2
Probable**	**10^{-n3}***	3
Frequent**	**10^{-n4}***	4

(*) n1>n2>n3>n4 ; (**) This is an example.

If the data used to estimate a level of probability offer the possibility of statistical handling, the results can arise in a form similar to column 2 of Table 1. In this context, the column 2 represents a quantitative scale.

In other situations where the data are offered less easily to this type of handling, different approach can be used according to nature and the quantity of the information (Figure 3).

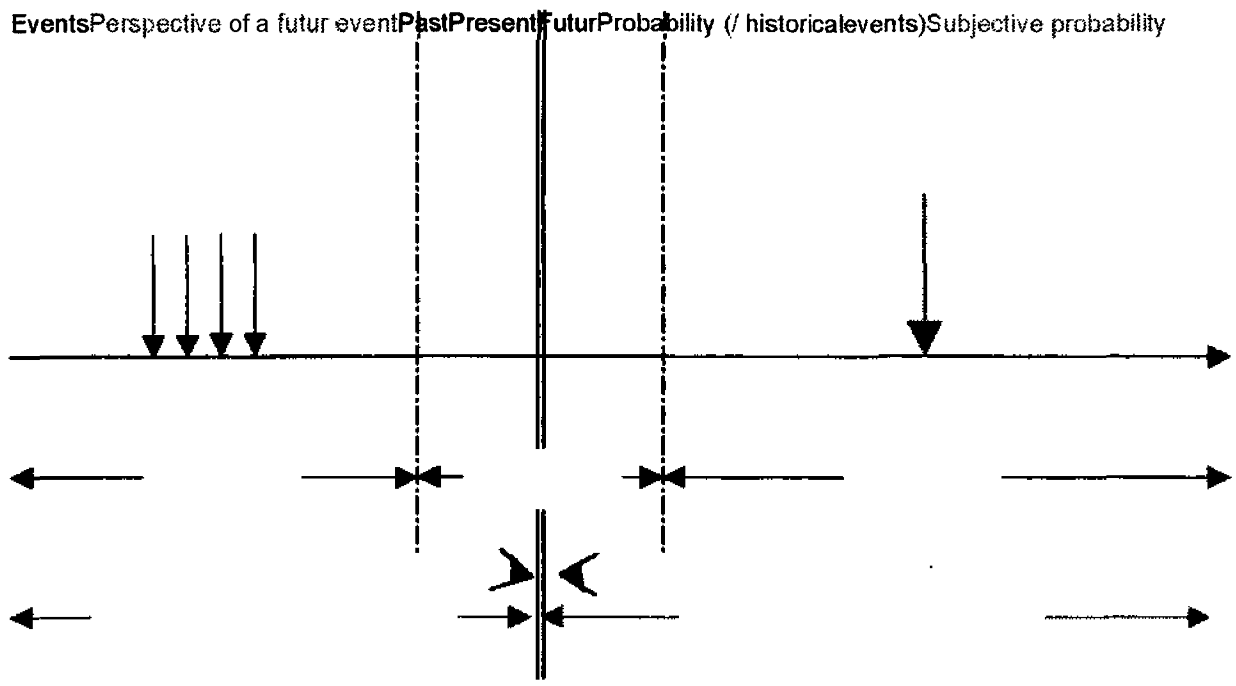


Figure 3. Statistical or expertise approaches to evaluate an occurrence of an event

The multiple-criteria approaches are an example of "expertise approach". This kind of approaches makes it possible to pass from a partial evaluation of a probability level (evaluation on several criteria) to a global evaluation of the probability level thanks to aggregation rules (Figure 4).

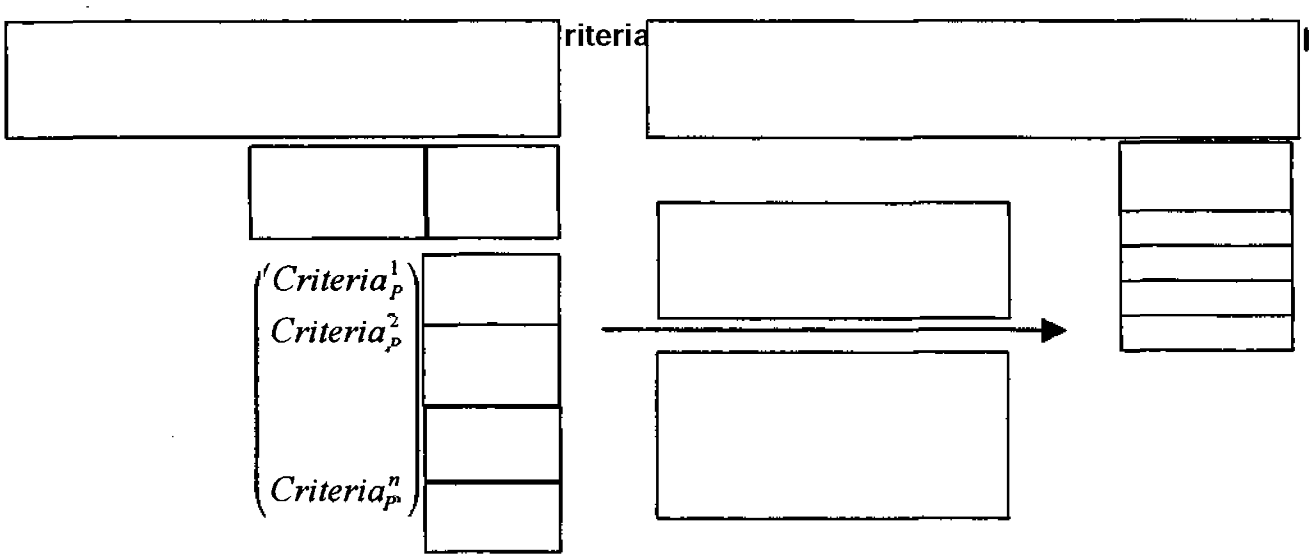


Figure 4. From a partial evaluation to a global evaluation of probability level

In the example Figure 4, the aggregate level of probability takes its value on an order numerical scale (column 3, Table 2).

b). *The level of gravity.* The analysis of the various evaluation methods, used to estimate a gravity level, shows the existence of a large variety of approaches to take into account several **targets(human**, technical, environmental, etc.) (Figure 5).

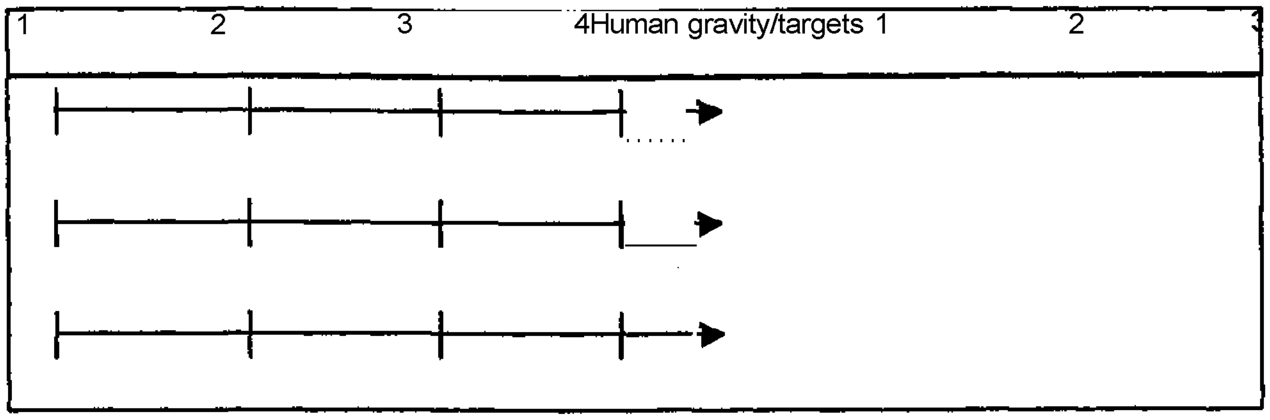


Figure 5. An example of a partial evaluation of **gravity** level

The use of qualitative scale or quantitative one depend on the nature of the available data and to the different actors involved in risk analysis process. If a global level of gravity is suitable, then it is important to consider the nature of the different partial gravity scales to choose the right aggregation rule.

The study of the "29 **criticality** grids" has shown that the most current aggregation rules were the "maximum logic" and the "weighted sum logic". The first one can give an **overestimation** of the gravity of scenario without considering the relative importance of the different targets. The second one can introduce important biases in the way the scenario are selected and considered as unacceptable. **Indeed**, if the partial gravity scales are qualitative one (verbal or numerical) than no numerical meaning can be given to the aggregate value.

3.2.2. Risk and acceptability evaluation

Once that the levels of probability and gravity were **identified**, the level of risk is obtained by positioning the scenario in the criticality grid. To avoid a loss of **information**, it seems preferable to indicate each scenario by the couple (gravity, probability of occurrence) rather than give a global evaluation of a level of risk.

This precaution aims at avoiding wrong use of aggregation rules and of focusing in risk evaluation rather than risk reduction measures. Thus, it is necessary to keep in mind that the purpose of positioning the set of scenarios in the criticality grid aims at choosing the right measures to reduce risk acting sometimes on probability level and sometimes in gravity level. According to this, the criticality grid can efficiently help to coordinate the actors in choosing the adequate risk reduction measures.

Positioning in the criticality grid makes it possible to visualize the various scenarios and to discuss of the risk reduction measures. The judgement on the risk acceptability or the risk non-acceptability of a scenario is a later stage. It makes it possible to distinguish, among the scenarios positioned on the grid, those that require an improvement in priority. The criticality grid must be used as a basis of dialogue to the technicians. So the levels of acceptability must reflect at this stage "what is technically acceptable "to reduce the level of risk of an unacceptable scenario (Figure 6).

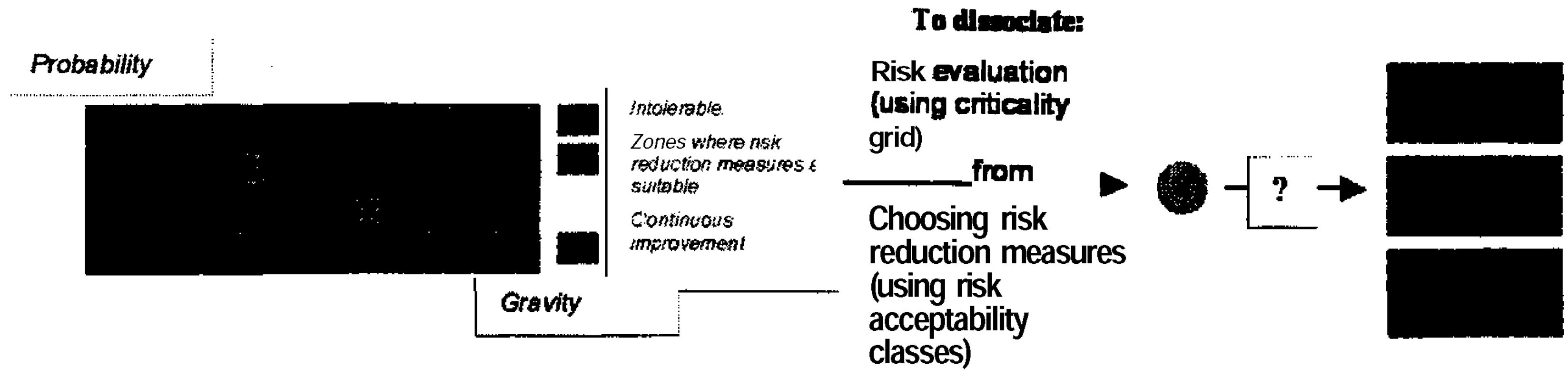


Figure 6. Two steps: Risk evaluation (G, P) and risk acceptability judgment

5. Risk Acceptability: Towards a Co-construction of measures to reduce vulnerability

The **TRPP** relate to "foreseeable technological events" and are not properly speaking a urban planning documents. But the Technological Risk Prevention Plans must be taken into account in Local Urbanization Plans.

The Technological Risk Prevention Plans (TRPP) includes three parts: a technical part, a regulation part, and a communication part. The TRPP aims at a stronger implication of the various actors concerned by risk prevention.

4.1. Technical measures for urbanization control

The technical part of the TRPP includes (i) informative maps (can come from the SS), (ii) a hazard map, (iii) a stakes map.

The TRPP aims at reducing the vulnerability around the Seveso sites notably by reducing vulnerability of the stakes. This consists in choosing a proportional risk reduction measure for urbanization control around Seveso sites. These measures refer concretely to a legal risk zoning which highlights the "zones" which would present the highest levels of risk according to the vulnerability of the stakes around the site. Crossing the hazard map and stakes map allows to make a first proposal of a set of measures for risk reduction. Theses measures, proposed by technical experts, consist in three urbanization constraints: expropriation, renunciation and pre-emption zones.

The regulation map (zoning) uses the technical zoning proposal done by technical experts. The regulation map of the Technical Risk Prevention Plans must consider local constrain. The Local Committee of Information and Dialogue **(LCID)** is in charge of carrying the local acceptability of the vulnerability reduction measures.

4.2. The mission of Local committee of Information and Dialogue(LCID) in Prevention Plans

The Table 3 shows the missions of the LCID in the TRPP. The LCID aims at accrediting the technical proposal and their adequacy to the local regional concerns in terms of risk prevention.

Table 3. The role of the LCID in TRPP process

Technological Risk Prevention Plan (TRPP)		Local Committee of Information and Dialogue (LCID)		
		Informed	Implied	Concerned
Technical part	A hazard map and a vulnerability map are produced under the responsibility of the competent services	☒		
Reglementary part	Came after the technical part		☒	
Communication part	Continuous.		☒	☒

The dialogue on the choice of risk reduction measures intervenes at various levels and in different ways at each step of the TRPP. Thus, the two sub-groups of experts in "hazard" and "Vulnerability" propose a first set of measures to reduce the risk. The Local Committees of Information and Dialogue (LCID) must "be informed" on the way technical advises are done. This information step aims at creating more proximity between experts and local risk prevention actors.

The first set of risks reduction measures are then submitted to the LCID. The LCID consult it's members and gives its conclusions. The dialogue aims at "considering the local conditions (ex. Economical, social, etc.) on the feasibility of the experts proposal measures.

In order to understand the conditions of a constructive dialogue within the framework of the Technological risk Prevention Plans (TRPP), INERIS has join the European project for an inclusive risk governance Trustnet-In-Action [27].

6. Conclusion

Risk cannot be dissociated from its perception. According to this point of view, this paper has studied the relation between "risk assessment and decision-making process", then "risk and acceptability".

In France, the promulgation of the law n° 2002-276 of February 27, 2002 relating to "the democracy of proximity" then more recently the law n° 2003-699 of July 30, 2003 relating to " technological and natural risks prevention and to damages compensation " highlights a need for a re-handling of the acceptability concept considered in Safety Studies (SS) and more recently within the framework of the Technological Risks Prevention Plans (TRPP).

In this paper, two kinds of acceptability were identified. The first one "technical acceptability" represents experts' agreement on the risk reduction measures proposed in the SS. The second one "social acceptability" is the result of a dialogue between the various groups of actor involved in risk prevention process (TRPP).

In the framework of the SS, the definition of acceptability is based on a decision-aid interface called "criticality grid". An analysis of about thirty grids made it possible to propose a set of suggestion to improve the way acceptability is estimated.

The acceptability within the urbanization control in the framework of the TRPP is captured using a dialogue process establish between the various actors represented in the Local committee of Information and Dialogue (LCID). This committee allows a local co-construction of risk prevention measures around Seveso sites. The European project "Trustnet-in-action" contributes to create the conditions of inclusive risk governance within the framework of the Local Committee in France.

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